

# VERTICAL AXIS ROTATIONAL MOTION CUES IN HOVERING FLIGHT SIMULATION

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## Extended Abstract

A previous study that examined how yaw motion affected a pilot's ability to perform realistic hovering flight tasks indicated that any amount of pure yaw motion had little-to-no effect on pilot performance<sup>1</sup> or opinion.<sup>2</sup> In that experiment, pilots were located at the vehicle's center of rotation; thus lateral or longitudinal accelerations were absent. The purpose of the new study described here was to investigate further these unanticipated results for additional flight tasks, but with the introduction of linear accelerations associated with yaw rotations when the pilot is not at the center of rotation.

The question of whether a yaw motion degree-of-freedom is necessary or not is important to government regulators who specify what simulator motions are necessary according to prescribed levels of simulator sophistication.<sup>3</sup> Currently, Ref. 3 specifies two levels of motion sophistication for flight simulators: full 6-degree-of-freedom and 3-degree-of-freedom. For the less sophisticated simulator, the assumed three degrees of freedom are pitch, roll, and heave. If other degrees of freedom are selected, which are different from these three, they must be qualified on a case-by-case basis. Picking the assumed three axes is reasonable and based upon experience, but little empirical data are available to support the selection of critical axes. Thus, the research described here is aimed at answering this question. The yaw and lateral degrees of freedom were selected to be examined first, and maneuvers were defined to uncouple these motions from changes in the gravity vector with respect to the pilot. This approach simplifies the problem to be examined.

For this experiment, the NASA Ames Vertical Motion Simulator was used in a comprehensive investigation. The math model was an AH-64 Apache in hover, which was identified from flight test data and had previously been validated by several AH-64 pilots.<sup>4</sup> The pilot's head was located 4.5 ft in front of the vehicle center of gravity, which is representative of the AH-64 pilot location. Six test pilots flew three tasks that were specifically designed to represent a broad class of situations in which both lateral and yaw motion cues may be useful. For the first task, the pilot controlled only the yaw axis and was required to rapidly acquire a North heading from 15 deg yaw offsets to either the East or West. This task allowed for full, or 1:1, motion to be used in all axes (yaw, lateral, and longitudinal). The second task was a 10 sec., 180 deg. pedal turn over a runway, but with the pilot only controlling the yaw degree-of-freedom. The position of the vehicle's center-of-mass remained fixed. This maneuver was taken from a current U.S. Army rotary wing design standard<sup>5</sup> and is representative of a

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maneuver performed for acceptance of military helicopters; however, it does not allow for full 1:1 motion, since the simulator cab cannot rotate 180 degs. The third task required the pilot to perform a rapid 9 ft climb at a constant heading. This task was challenging, because rapid collective lever movement in the unaugmented AH-64 results in a substantial yawing moment (due to engine torque) that must be countered by the pilot. This task also had full motion in all axes, but, in this case, the pilot had two axes to control simultaneously, rather than one as in the previous tasks.

Four motion configurations were examined for each task: full motion (except for the 180 deg turn, for which the motion system was configured to provide as much motion as possible), full linear with no yaw motion, full yaw with no linear motion, and no motion. Each configuration was flown four times in a randomized test matrix, and the pilots were not informed of the configuration given. Vehicle state data were recorded for objective performance comparisons, and pilots provided subjective comments and ratings. As part of the pilots' evaluation, they were asked to rate the compensation required, the overall fidelity of the motion as compared to real flight, and whether motion was detected or not in each of the six degrees of freedom. In addition, the pilots provided a numerical level-of-confidence rating, between 1 and 7, corresponding to how sure they were whether or not motion was present in each degree-of-freedom. The latter ratings allow classical signal detection analysis to be performed.

Several analyses of variance have been conducted to date. One result indicates that when only lateral translational motion was present, pilots also felt that yaw rotational motion was present. It is believed that the sensation of yaw rotation was induced by the combination of compelling visual cues during a yaw maneuver along with the lateral acceleration cue. On the other hand, when only yaw motion was present, pilots tended to sensed some motion, but had difficulty in attributing the motion to the correct axis. The addition of yaw motion neither resulted in an improvement in performance nor in the level of compensation required. However, performance improved and compensation decreased when lateral motion was present regardless of the existence of yaw motion.

These preliminary results indicate that the yaw degree of freedom in hovering flight simulation may not be necessary, and that the combination of some lateral motion with a compelling visual scene may be all that is necessary to make pilots believe that physical yaw motion is present. The paper will provide a full background on the above topic along with a full presentation of all the data and relevant results.

### **References**

<sup>1</sup>Schroeder, J. A., "Simulation Motion Effects on Single Axis Compensatory Tracking," *AIAA Flight Simulation Technologies Conference, A Collection of Technical Papers*, Monterey, CA, Aug., 1993, pp. 202-213.

<sup>2</sup>Schroeder, J. A., "Evaluation of Simulation Fidelity Criteria in the Vertical and Directional Axes," *49th Annual Forum Proceedings of the American Helicopter Society*, St. Louis, MO, May, 1993, pp. 419-437.

<sup>3</sup>*Helicopter Simulator Qualification* (DRAFT), Federal Aviation Administration Advisory Circular AC-120-xx, July, 1992.

<sup>4</sup>Schroeder, J.A., Tischler, M.B., Watson, D.C., and Eshow, M.M., "Identification and Simulation Evaluation of an AH-64 Helicopter Hover Math Model," *AIAA Atmospheric Flight Mechanics Conference, A Collection of Technical Papers*, New Orleans, LA, Aug. 1991, pp. 264-297.

<sup>5</sup>*Airworthiness Design Standard, Handling Qualities, Rotary Wing*, U.S. Army AVSCOM ADS-33, May. 1987.